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# A Method to Support Hikers in Natural Areas in the Selection of Paths Tailored for them

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**Abstract:** Hiking can provide rural economic development as well as a variety of benefits on the community of walkers, including improved fitness and public health. That is why, many communities are expanding their attention in developing and maintaining recreational trails as tourist attractions to stimulate economic growth. Nowadays, the more widespread way of serving hikers by regional authorities consists in the development of web sites about trials. Unfortunately, the existing sites are unsatisfactory because they display, in a sort of digital shop window, all the paths surveyed leaving to the hikers the decision of choosing one. This study first makes the conjecture that two factors are relevant in the hiking domain called: human factor and motivational factor. Then, building on such an assumption, it proposes a method for selecting the set of paths that best fit the profile and motivations of a specific hiker, hopefully by preventing that he runs into accident hazards and/or health risks during the excursion.

**Key words:** Hiking, hiking path, human factor, motivational factor, hazards

## INTRODUCTION

Hiking is commonly defined as all kinds of physical activities that involve walking in the countryside, the forest or the mountains along trails. Annually, >100 million hikers are attracted by the natural areas around the world (Burtscher and Ponchia, 2010).

There are many sources that quantify the positive effects of the environmental hiking on the economy of the rural areas where such activities take place (Mayer *et al*., 2010; Bryden *et al*., 2010; Bowker *et al*., 2007; Litman, 2004).

To exploit the vast natural beauty that most countries in the world can boast with the important economic return just mentioned, government agencies and private organizations must therefore, provide adequate support to the hikers. This issue is strongly felt in Italy too where the enhancement of the national landscape is a law obligation for the Italian Regions since, 2004 (MNHC, 2004).

In the remainder of the study, researchers use the terms path/route to denote a sequence of trails; in turn (according to the Italian Code of the road, Art. 3, n.48-http://it.wikipedia.org/wiki/Codice_della _strada), a trial is a road formed by the passage of pedestrians and animals.

**Issues related to hiking:** After reviewing the extensive literature that relates to hiking, researchers are able to affirm the relevance of the following four issues: physical well-being, health hazards, risk of accidents and hiker satisfaction. Below, researchers will give a brief summary for each of them to motivate the assumptions underlying the proposal.

**Physical well-being:** Walking can provide comparable health benefits as vigorous exercise with fewer risks (Pate *et al*., 1995; Brownson *et al*., 2000). Unfortunately, an increasing portion of the population including children, lacks regular physical activity. This finding motivated many studies looking for strategies suitable to encourage citizens to make a regular physical activity. The development of the so-called community trails, for example is a quite recent strategy to increase physical activity among community residents (Reed *et al*., 2004).

Hiking can have positive therapeutic implications even for not healthy people. Many studies have been carried out on the topic since the 1970s (Schobersberger *et al*., 2010).

**Health hazards:** Many studies (Honigman *et al*., 1993; Barry and Pollard, 2003) testify that people walking altitudes above 2000 m commonly experience acute mountain sickness. Very recently, Dallimore *et al*. (2012) observed the appearance of similar symptoms of altitude sickness at low elevations (<500 m) during a short trekking trip.

Feuerecker *et al*. (2012) report about the effects that may be induced even in healthy man from doing strenuous physical activity between 2000 and 3000 m without caution. Unfortunately, the potential risks to occasional hikers in mountains are even bigger as researchers read in (Burtscher and Ponchia, 2010):

> Sudden cardiac death is the most frequent cause of nontraumatic death in males older than 34 years at altitude during leisure time activities such as downhill skiing and hiking. Unaccustomed physical activity seems more likely to trigger sudden cardiac death than altitude per se

Other studies about the risk of sudden cardiac death during mountain hiking are reported by Windsor *et al.* (2009) and Burtscher *et al.* (2007).

**Risks of accidents:** The risk of accidents in the hiking context might seem pure alarmism but in the reality this is not the case. A major cause of risk is ascribable to the fact that many hikers are attracted by natural areas but most natural areas are (by definition) undeveloped as the primary objective is to conserve the habitat and the animal species living in those places. So, those areas are not geared towards visitation.

Boulware (2004) reports that a frequent reason for abandoning hiking earlier than planned is because of injuries (20% for women vs. 25% for men). The events that influence mountain accidents are of four categories (Chamarro and Fernandez-Castro, 2009): environmental events, medical events, human errors and time pressure. The environmental events include: difficulty (i.e., the wrong estimates of the strength and stamina required) weather conditions and environmental conditions. The most common medical events are related to the fatigue triggered by the activity itself. One special type of human error is the lack of adequate training.

**Hiker satisfaction:** The study by Denstadli and Jacobsen (2011) indicates that it is important to take into consideration the motorists, desire to experience attractive sceneries in order to increase overall route satisfaction. In turn, satisfaction is demonstrated to significantly increase route loyalty. Migrating these findings in the hiking context, the assumption is that giving to the hiker the chance to walk along paths source of positive emotions, increases greatly the likelihood that he will repeat in the future those trips besides talking positively about them to his friends/colleagues. There are many studies that have investigated the direct link between the tourist's satisfaction and his intention to return to the same destination (Alegre and Garau, 2010; Lee *et al*., 2011).

This study aims at laying the foundations for helping the regional authorities with responsibility of management and development of the territory to make available a personalized hiking service to the growing community of hikers in natural areas. The kernel of the proposal is a new approach for the identification of the paths (among those collected into a spatial database resident on some server) to be returned to the subjects registered to the service.

## FACTORS OF THE HIKING DOMAIN

In the light of the issues outlined in study, it appears crucial the need to support natural area hikers in the choice of the path of the "next" excursion. Researchers propose a method to do that based on two independent and somehow complementary factors called, the human factor and the motivational factor. The link between those factors and the issues in study is summarized in Table 1.

**Human factor:** Because a path to be proposed to the hiker might be suitable to him, it has to be selected by taking into account his physical characteristics (e.g., age, height, weight, etc.) as well as his physical training. Otherwise, it is real the risk that the potential physical well-being that he could derive from walking in a natural environment is dominated by the dangers to his health (Table 1). In practical terms, this means that the hiker must be guided in the choice of the path.

**Motivational factor:** According to Torbidoni (2011), every hiker has at least one motivation for hiking. Moreover, from the field of tourism we learn that there is a direct relationship between motivation and visitor satisfaction (Devesa *et al*., 2010). Many factors contribute to the determination of the motivations. For example, a very recent study by Morey and Thiene (2012) is based on the conjecture that for many recreational activities, a significant amount of the variation in the sites visited can be explained and hence predicted by taking into account the simultaneous variation of what they call "life constraints" (namely: correlated variables such as marital status, number of kids, body-mass index, fitness, skill, disease, resting heart rate, alcohol consumption, cigarette consumption, blood pressure, etc.).

The motivational factor is meant to capture the hikers' heterogeneity as well as to acknowledge the direct link between motivation and hiker satisfaction (Table 1).

Table 1: The factors of the hiking domain vs. the issues from the state of the art

| Factors | Issues |
|---|---|
| Human | Physical well-being, health hazards and risks of accidents |
| Motivational | Hiker satisfaction |

## SELECTION OF PATHS: A METHODOLOGICAL PROPOSAL

In the remainder of the study, researchers denote as N and M the total number of Paths (P) and Hikers (H), respectively. Formally, $P = \{p_1, p_2, ..., p_N\}$ and $H = \{h_1, h_2, ..., h_M\}$ while p and h denote, in order, the generic path and the generic hiker.

This study proposes an innovative solution to the problem of selecting a sub-set (eventually empty) of paths from P suitable to a specific hiker ($h \in H$) by mapping the two factors of the hiking domain into quantitative parameters identified with respect to the space of paths and the space of hikers, i.e., two 2D spaces whose dimensions take the names from those two factors.

**Human dimension:** Having adopted this denomination is equivalent to put at the center of the attention the hiker to be "served". Obviously, researchers may give distinct names to this dimension depending on whether we refer to the hikers' space or to the paths' space but this overloading is unnecessary.

Researchers call stretch of p each portion of the path delimited by a variation of the gradient of the terrain. We use the parameter E (xertion) (expressed in kilometers) to quantify the human dimension. In the space of paths, $E_p$ defines the inherent (alias technical) difficulty of each trail. The quantification of $E_p$ is obtained by means of Eq. 1:

$$E_p = \sum_{i=1}^{Q} \frac{L_i + D_i}{L_i} \quad \text{if } D_i < 0, \text{ set } D_i/L_i = 0 \tag{1}$$

Where:

Q = The number of stretches of path p
$L_i$ = The length of the generic stretch of p ( km)
$D_i$ = Altitude variation (km)

Equation 1 is based on the consideration that for a given path extension, the physical effort required to complete the excursion is affected by the changes in the elevation. These latter, in turn are much more tiring the shorter is the length of the stretch of the path in which they arise. For example, a rise of 100 m weighs in very different ways when it occurs in a stretch of 500 m rather than 2000 m. The factor $D_i/L_i$ of Eq.1 captures this aspect. Equation 1 proposes an increase of the length of the path only for uphill stretches.

For example, for the path of Fig. 1, the value of $E_p$ is obtained by adding five terms (Q = 5), one for each stretch of the path:

$$E_p = (1.45+0.4/1.45)+(0.61)+(0.8)+ (1.24+0.3/1.24)+(0.8) = 5.41 \text{ km}$$

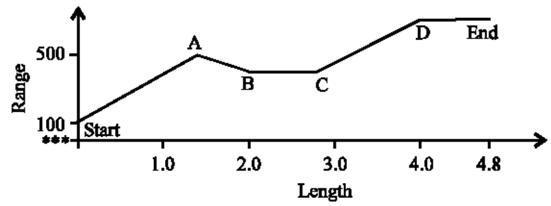


Fig. 1: A path of length 4.9 km and elevation ranging from 100 m up to 700 m

The extension of the generic stretch of p is computed by applying the Pythagoras' theorem. As it can be seen, in view of a path of 4.9 km (= 1.45+0.61+0.8+1.24+0.8) of nominal length, it happens that the exertion required is equal to 5.41 km and this because of the altitude variations.

With regard to the hiker space, the human dimension is quantified by the hiker maximum sustainable exertion ($E_h$) calculated by taking into account his age, height, weight and training according to Eq. 2:

$$E_h = (\nu_a \times \nu_w \times \nu_t) \times E_{nom} \tag{2}$$

where, $E_{nom}$ is the maximum nominal exertion that hiker h can afford in a day-walk while $\nu_a$, $\nu_w$ and $\nu_t$ are the values returned by the functions $V_a$, $V_w$ and $V_t$ linked, in sequence, to the age, physical well-being and training of h. For a given hiker, the three functions assume a value between 0 and 1.0, the lower extreme not included. The purpose of Eq. 2 is to adapt the value of $E_{nom}$ to the characteristics of the hiker.

In the literature about hiking as far as researchers know, the differences between the sexes have been little studied. The only research that researchers have found, Boulware (2004) reports a study whose objective was to compare women with men backpackers to determine the extent to which injuries and illnesses limit endurance outdoor recreational activities. Boulware (2004) concludes that "women had similar experiences as compared with men when backpacking". That is why, Eq. 2 does not contain a link to the hiker sex.

Researchers set the value of $E_{nom}$ to 24 km because of an empirical rule shared among the hikers that says that to cover 1 km of flat trail takes 15 min and after 1 h walk a hiker has to take a break of 15 min. Therefore, by assuming a day-excursion of 8 h, the hiker has a total of 6 actual hours in which he may cover at most 24 km. Of course the value of $E_{nom}$ may be changed without affecting the method.

A hiker with human factor equal to $HF(h) = E_h$ can face paths characterized by a Human Factor $HF(p) = E_p$ such that condition:

$$E_p \leq E_h \tag{3}$$

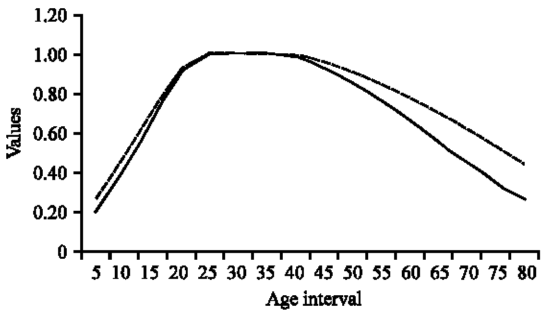


Fig. 2: Two slight variants of the trend of function $V_a$

holds. To evaluate Eq. 3, functions $V_a$, $V_w$ and $V_t$ have to be chosen.

**Function $V_a$:** Aim of this function is to establish a correlation between the hiker age and $E_{nom}$. The qualitative trend of $V_a$ is an asymmetrical bell with respect to the vertical axis (Fig. 2), in fact it is easy to guess that the magnitude of the maximum sustainable physical effort by a hiker increases with his age up to a maximum that is maintained for a range of values of age and then decreases slowly. The asymmetry stems from the fact that human beings reach at young age the peak of their physical performance that slowly they lose over the years. The uncertainties related to the choice of a specific function concern: the width of the flat portion of the function (Fig. 2), the curve ascent/descent gradient and its initial value. The best way to make a conscious and satisfactory choice of function $V_a$ implies that one starts with a function that approximates the trend of Fig. 2 then it will be necessary to make recourse to an empirical phase for the final tuning of the function's parameters. At this stage of the research, researchers propose Eq. 4. The value 2.718 is the well-known Euler number:

$$V_a = \begin{cases} 2.718^{-(age-25)^2/250} & \text{if age} < 25 \\ 1 & \text{if age} \geq 25 \text{ and age} \leq 35 \\ 2.718^{-(age-35)^2/1,500} & \text{if age} > 35 \end{cases} \quad (4)$$

The curves in Fig. 2 show the trend of $V_a$ in the age interval between 5 and 80 years. By varying the value of the denominator of the exponent, it changes the slope of the curve in the two sloping stretches. For example, the green curve of Fig. 2 corresponds to the values 300 and 2,500 whose effects are to increase the slope of the rising section of $V_a$ and slow the slope of the descending portion of the curve.

Table 2: Nutritional status of an individual

| Categories | BMI |
|---|---|
| Underweight | <18.5 |
| Normal (healthy weight) | 18.5-25 |
| Overweight | 25-30 |
| Moderately obese | 30-35 |
| Severely obese | 35-40 |
| Very severely obese | Over 40 |

**Function $V_w$:** $V_w$ takes into account what researchers have called the physical well-being connected to the maximum exertion that a hiker can face without that his body suffers. The basic consideration is that the maximum sustainable effort by a person overweight (or under weight) should be less than that bearable by one whose weight is in the norm. To assess the physical state of a hiker we use the Body Mass Index (BMI) defined as:

$$BMI = Mass/Height^2$$

where, mass is in kg and the height in m. The value of BMI is put in relation with what proposed by the World Health Organization (http://en.wikipedia. org/wiki/ Body_ mass_index) and summarized in Table 2. The BMI is largely used in experimental studies (Perrey and Fabre, 2008).

Even the qualitative behavior of $V_w$ is a bell-like. In fact, the extent of the effort sustainable by a hiker increases as the value of his BMI moves towards 18.5, to which it corresponds the maximum sustainable effort by him. The maximum value is maintained until BMI does not exceed the value 25 and then it decreases. The uncertainties related to the choice of a specific function $V_w$ affect the gradient of ascent/descent of such curve. Once again, the correct approach to arrive at a conscious and satisfactory choice of $V_w$ implies to have recourse to an experimental phase. At this stage of the research, function $V_w$ is defined by Eq. 5:

$$V_w = \begin{cases} 2.718^{-(BMI-18.5)^2/50} & \text{if BMI} < 18.5 \\ 1 & \text{if BMI} \geq 18.5 \text{ and BMI} \leq 25 \\ 2.718^{-(BMI-25)^2/50} & \text{if BMI} > 25 \end{cases} \quad (5)$$

Figure 3 shows the trend of $V_w$ for values of BMI between 15 and 45. When BMI exceeds 40, the value of $V_w$ is ~0. From Eq. 2, it follows that $E_h$ is equal to zero and from this it follows that to the hiker with such a profile should not be proposed routes at all because of the strong obesity that may endanger his physical safety.

**Function $V_t$:** Aim of this function is to establish a correlation between the hiker training and $E_{nom}$. It is defined as follows:

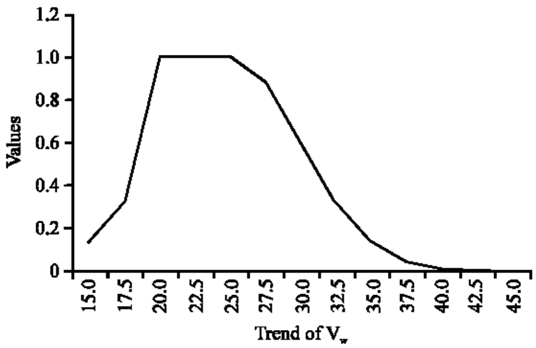


Fig. 3: The trend of function $V_w$

Table 3: The inherent difficulty of the four paths in P

| P | $E_p$ (km) |
|---|---|
| $p_1$ | 23.0 |
| $p_2$ | 4.0 |
| $p_3$ | 5.5 |
| $p_4$ | 8.5 |

$$V_t = \frac{F_{past}}{E_{nom}} \quad (6)$$

Where:

$$E_{past} = \sum_{k=1}^{N_h} \frac{E_p(k)}{N_h} \quad (7)$$

where, $E_{past}$ is the average effort supported by h in the ($N_h$) excursions he carried out in the 12 months that precede the day when he looks for a new path, therefore called past effort.

An example: let P = {$p_1$, $p_2$, $p_3$, $p_4$}. Table 3 gives the inherent difficulty of each trail. Moreover, let us refer to a hypothetic hiker (h) whose characteristics (age, BMI and training) give rise to $E_h$ = 14.5. Therefore, it will be correct to propose to h paths $p_2$, $p_3$ and $p_4$ but not $p_1$.

**Motivational dimension:** To the name given to this dimension applies the same explanation of the previous one. The motivational dimension identifies, in the hikers' space, their reasons for looking for the next path and in the paths' space the path attributes. Let:

- MF = {$mf_1$, $mf_2$, ..., $mf_l$} be the set of the possible reasons why a hiker might want to take a route
- MF(p)⊆MF be the set of the attributes of path p
- MF(h)⊆MF be the reasons why hiker h wants to walk along path p

Then, path p is of interest of hiker h if and only if MF(h)⊆MF(p). An example: the hypothesis:

- MF = {peak, naturalistic, historical, religious}
- P = {$p_1$, $p_2$, $p_3$, $p_4$}
- MF($p_1$) = {peak, naturalistic}
- MF($p_2$) = {historical}
- MF($p_3$) = {religious, historical}
- MF($p_4$) = {peak, religious}
- MF(h) = {historical} (i.e., hiker h is interested to a historical route)

It follows that it is correct to return to h only paths $p_2$ and $p_3$.

**Determination of the set of paths suitable for a hiker:** First of all it is necessary to compute: (HF(p), MF(p)) ∀p∈P and HF(h), MF(h) then, the paths to be returned to hiker h is the set composed of those satisfying the following conditions:

$$(HF(p) \leq HF(h) \wedge MF(p) \supseteq MF(h)) \; (\forall p \in P) \quad (8)$$

## DISCUSSION

**Current methods and technologies:** The methods for planning an excursion and the supporting technologies range from the use of a paper-based topographic map (the classic method) to the use of digital maps and lastly to have recourse to the web portals about trials. This study evaluates these three alternatives with respect to the approach.

**Topographic map vs. the factors of the hiking domain:** The human factor is ignored. After planning the route, it is only possible to determine its length and elevation. A direct knowledge of the territory by the hiker can preserve him against surprises not necessarily pleasant. The motivational factor is inherent in the route choice by the hiker, choice likely driven by his needs and desires.

**Digital (vector) maps of paths vs. the factors of the hiking domain:** Digital (vector) maps of paths reproduce what has been already done with success in the automotive domain. Garmin, for example, sells GPS navigators equipped with a free software (BaseCamp) for Windows and Mac (http://adventures.garmin.com/en-US/) and territorial maps on payment about various countries around the world. For example, for Italy the version on the market is Garmin TrekMap Italia v3 PRO (http://www.garmin.com/it/trekmapitalia), a topographic vector map at the scale 1:25 K.

This solution does not take into account the two factors of the hiking domain in building the path to be proposed to the user. Therefore, the usage of products like BaseCamp by novice hikers is not advisable because

Table 4: Summary of the discussed alternatives

| Examples | Classic Method (IGM 25DB) | Digital vector map (Garmin TrekMap Italia) | Web portal (Sentieri Web) |
|---|---|---|---|
| Coverage of the Italian territory | 100% | Less than a half of the Italian territory, mostly in the North of the country | Emilia Romagna |
| Route selection | Difficult | Long | Long |
| Material for route selection | Pen, paper, ruler | PC, BaseCamp | PC, browser |
| Usage on the ground | Difficult | Easy (GPS) | Easy (GPS) |
| Equipment on the ground | Magnetic compass, altimeter | GPS compatible | Cartographic GPS |
| Cost | €9 (for each map) | €199.00 | Free |
| Cost of extra equipment | €80 | €199.00 | Free |
| Human factor | Ignored | Ignored | Partially supported |
| Motivational factor | Inherent | Ignored | Ignored |

there is no certainty that the route proposed by the system meets his desires and moreover that it does not present difficulties beyond his ability.

**Web portals:** The latest trend is to build/display web portals dedicated to hiking. Millesentieri, Gulliver (http://www.gulliver.it/escursionismo/) and Sentieri Web are representative portals for the Italian territory. In the following researchers focus on Sentieri Web.

The portal Sentieri Web (http://sentieriweb.regione.emilia-romagna.it/-an English version is available) is about trails in the hilly and mountainous region of Emilia Romagna. Hiker can consult the routes available by entering the name of the place of departure and arrival or he can select the points directly on the map moreover, the user of the portal can enter the maximum duration (in hours) of the excursion he is looking for and the maximum technical difficulty (according to CAI classification-the Club Alpino Italiano, http://www.cai.it/ is a national association linked to the hiking). The system returns a series of itineraries and for each of them it is specified the difficulty, the length in meters, the round trip travel time to return, climb and descent. Moreover, information about the presence of structures and refuges with contact information, opening times and the nearest public transportation stops are displayed. Routes of interest can be downloaded in digital format for use on mobile devices or handheld devices. Three formats are available: GPX (for use with GPS navigation systems), KML (for use with Google Maps/Earth) and SHP.

**Sentieri web vs. the factors of the hiking domain:** The motivational factor is not taken into account in the construction of the path to be returned to the applicant, while the human factor is partially supported. Widening the view: http://wanderland.myswitzerland.com/en/routen.cfm and http://www.mapmyhike.com/imapmy/ are the URL of two web portals for hiking, the first within Europe and the other in America among the many that exist. These sites too suffer from the limitations mentioned above with respect to the two dimensions proposed in this research. Table 4 summarizes the features of the methods recalled in this study focusing on Italy as well as their comparison against the two dimensions of the hiking context.

## CONCLUSION

This study has laid the foundation to make available a personalized hiking service to the growing community of hikers of natural areas. The kernel of the proposal is the new approach on which is based the identification of the paths (among those collected into a spatial database resident on some server) to be returned to the subjects registered to the service. The approach is based on two independent factors (human and motivational) that take into account the physical characteristics of the hiker and his interests and compare them with the difficulties of the paths and the attractions they offer.

The proposal overcomes the paradigm of the sites present on the net that expose, in a sort of digital shop window, all the paths surveyed leaving to the hikers the decision of choosing one. The main limitations of such an approach lie in the slow exploration of the offer by the hiker and the danger that he can do wrong choices, running into accident hazards and/or risks for his health during the excursion.

## LIMITATIONS

The main limitation in this study relates to the lacking of an empirical validation of the proposed model. An empirical stage offers us the chance to carry out the fine tuning of the formulas of the human dimension, especially those containing constants. This is the subject of future research. Unfortunately, to validate the model are required data on a large number of hikers and paths over a long period of time. Data that for the time being are not in the possession.

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